Viscosity and Surface Tension of High-Viscosity Fluids from Surface Light Scattering (SLS)

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Light scattering by thermally excited capillary waves on liquid surfaces in macroscopic thermodynamic equilibrium can be used for the investigation of viscoelastic properties of fluids. For the propagation of capillary waves in the case of small fluid viscosity and/or large surface tension it has been already demonstrated by our previous research activities for the reference fluid toluene as well as for numerous pure refrigerants and their mixtures from the group of partially fluorinated hydrocarbons that the surface light scattering (SLS) technique can be used for a reliable determination of surface tension and liquid viscosity with an accuracy comparable or even better than that one of conventional methods. In contrast, for an over-damped behavior of surface fluctuations in the case of large fluid viscosity and/or small surface tension the SLS technique so far serves rather as a check of the hydrodynamic theory connected with the capillary wave problem.

Within the scope of the measurement of transport and other thermophysical properties of fluids, in the present work - to the best of our knowledge - for the first time high-viscosity fluids have also been studied using the SLS technique. Here, in complete analogy to our former SLS measurements for the propagating case an experimental set-up is used which enables to measure the capillary wave characteristics in forward scattering direction at variable and relatively high wave numbers. Also for an over-damped behavior of surface fluctuations the experiments rely on a heterodyne detection scheme and signal analysis by photon correlation spectroscopy (PCS). Results for the dynamic viscosity and surface tension are shown for a silicone oil and diisodecyl-phthalate over a wide temperature range. The latter one has been proposed by the former "IUPAC-Subcommittee on Transport Properties" as a new viscosity standard for high-viscosity fluids. The present data demonstrate the applicability of the technique to fluids covering a wide range of viscosity, from about 10 mPas to 1 Pas with an inaccuracy of smaller than 1 %. Yet, a value of 1 Pas seems not to be the upper limit of the viscosity range that could be investigated by the SLS technique. An estimation based on the time domain between a few nanoseconds to several hundred milliseconds where PCS can be applied in a sensible way indicates for the upper limit of the viscosity value of order of magnitude of 1 kPas.